PROGRAM ANNOUNCEMENT

Fiscal Year 2006 Test and Evaluation (T&E) Research Program

AFOSR BAA 2006-

PROPOSAL DEADLINE:
4:00 p.m. Eastern Standard Time
Thursday, 5 Jan 2006

<u>OVERVIEW INFORMATION</u>

- **Agency Name(s) –**The Air Force Office of Scientific Research (AFOSR) in cooperation with Arnold Engineering Development Center (AEDC), Air Force Flight Test Center (AFFTC) and Air Armament Center (AAC)

- **Funding Opportunity Title –** *Fiscal Year 2006 Test and Evaluation (T&E) Research Program*

- **Announcement Type –** This is the initial announcement.

- **Funding Opportunity Number -** AFOSR BAA 2006-.

- **Catalog of Federal Domestic Assistance (CFDA Number(s) –** 12.800 **-** Air Force Defense Research Sciences Program.

- **Dates –** Proposals must be received by 4:00PM Eastern Daylight Time, 5 Jan 2006

- **Additional Overview Content-- The tasks listed below represent basic research needs identified by the Air Force Test and Evaluation Community. AFOSR and the T&E Community agree that successful research efforts in these areas can be transitioned to the T&E Centers and will have significant impact on important challenges facing these Centers.**

I. Funding Opportunity Description

- The tasks listed below represent basic research needs identified by the Air Force Test and Evaluation Community. AFOSR and the T&E Community agree that successful research efforts in these areas can be transitioned to the T&E Centers and will have significant impact on important challenges facing these Centers.

II. Award Information

The anticipated types of awards are grants, cooperative agreements or contracts. Each project selected will be funded at approximately $100 K per year for a maximum of three years. The number of efforts selected for funding will be subject to the amount of funds available.

III. Eligibility Information

1. **Eligible Applicants –** This competition is open to all respondents.

Proposals are encouraged from historically Black colleges and universities and minority institutions (HBCU/MI), as defined by 10 U.S.C. 2323. Accredited U.S. postsecondary institutions that meet the statutory criteria for identification as minority institutions are listed at the following Department of Education web site: http://www.ed.gov/about/officer/kust/ocr/edlite-minorityinst.html.

However, no funds are specifically allocated for HBCU/MI participation.

2. **Cost Sharing or Matching –** Cost Sharing is not required.

3. **Other –** Some research projects may require access to unclassified-sensitive information that will require additional agreement with that Test and Evaluation Center. In these cases, publications may require review by the Air Force prior to public release.

There are no limits to the number of applications an applicant may submit.

IV. Application and Submission Information

1. **Address to Request Application Package:** Consult the AFOSR web page: www.afosr.af.mil. Directly under the AFOSR logo on the home page is "Doing Business with AFOSR". The first listing under this topic is "How to Apply for a Grant or Contract". Full details of proposal content and form are given there. Download and complete the proposal Cover Page. In the block "Title of Proposed Project", add the following:

Solicitation Title: Test and Evaluation Research Program.

2. **Content and Form of Application Submission:** Using the budget forms available on the AFOSR web page, applicants should prepare three 12-month budgets and an aggregate 36-month

budget beginning 01 March 2006, the anticipated start date of successful applications. Proposals should not exceed 25 total pages typed in 10 or 12 point font, including cover page and budget. Proposals exceeding this limit will not be considered.

Ten paper copies of the proposal should be submitted to Dr. John D. Schmisseur:

Air Force Office of Scientific Research
ATTN: John D. Schmisseur -NA
875 North Randolph Street
Suite 325, Room 3112
Arlington, Virginia 22203

Attn: Test and Evaluation Research Program

Applicants will be notified by mail that their proposal has been received by AFOSR.

3. Submission Dates and Time: Proposals must be received at AFOSR by 4:00 PM, EST, 5 Jan 2005

4. Intergovernmental Review: None

5. Funding Restrictions: None

6. Other Submission Requirements. Only hard copy submissions will be accepted. Submission by facsimile, e-mail or other electronic media will not be accepted in whole or in part. The proposal must be complete and self-contained to qualify for review.

V. Application Review Information

1. Criteria: Proposals under this Broad Agency Announcement (BAA) will be evaluated through a peer or scientific review process, and selected for award on a competitive basis according to Public Law 98-369, Competition in Contracting Act of 1984, 10 U S C 2361, and 10 U S C 2374. All proposals will be evaluated under the following two primary criteria, of equal importance, as follows:

1. The scientific and technical merits of the proposed research.

2. The potential contributions of the proposed research to the mission of the Air Force.

Other evaluation criteria used in the technical reviews, which are of lesser importance than the primary criteria and of equal importance to each other, are as follows:

1. The likelihood of the proposed effort to develop new research capabilities and broaden the research base in support of national defense.

2. The proposer's principal investigator's, team leader's, or key personnel's qualifications, capabilities, related experience, facilities, or techniques or a combination of these factors that is integral to achieving Air Force objectives.

3. The proposer's and associated personnel's record of past performance.

4. The realism and reasonableness of proposed costs and availability of funds, although not a primary evaluation factor, price is a substantial factor in the selection of proposals for award.

No further evaluation criteria will be used in source selection. The technical and cost information will be analyzed simultaneously during the evaluation process.

VI. Award Administration Information:

1. Award Notices: Principal Investigators of successful proposals will receive a notice, by letter or e-mail, on or about 30 January 2006. For those proposals being recommended for an award, the notification should not be regarded as an authorization to commit or expend funds. Proposals selected for funding as grants or cooperative agreements may include, at the recipient's own risk and to the extent that the recipient organization allows, charging to awards of 90 days pre-award costs. Negotiations may result in funding levels that are less than proposed. Only an award document signed by a Government Contracting/Grants Officer will bind the Government.

2. Administrative Requirements: AFOSR's terms and conditions for grants are available at the AFOSR web page: www.afosr.af.mil. Directly under the AFOSR logo on the home page is "Doing Business with AFOSR".

3. Reporting: A performance report will be due to AFOSR each year and a final technical report will be due after completion of the research. For report content see www.afosr.af.mil/pdfs/performancereportsMarch2000.pdf . For grants and cooperative agreements, Financial Report using SF-269 (or SF-272) is required by Part 32 of the DoD Grant and Agreement Regulations (32 CFR part 32).

VII. Agency Contract(s): Address questions to:

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1. Automated Calibration of Turbine Performance Simulations Using Optimum Robust Estimation of Engine Model Parameters

A key step in the turbine engine developmental and qualification testing process is building an accurate and complete mathematical simulation (i.e. model) of engine performance over the entire operational envelope. This model enables greater validation of the test asset and reduces engine test time. Because of the complexity of the engine system, the models are inaccurate. Accuracy can be greatly improved by adjusting the models during engine test using acquired test data.

In this way, a nominal engine model is "tuned" using the observed test data to yield the best possible agreement between model predictions and actual engine performance. This is a highly complex process involving multidisciplinary engineering and advanced mathematics. Turbine engine models are highly nonlinear, and contain dozens of parameters with which to "tune" the model during the matching process. Moreover, the test data used for the match may range from a half-dozen sensor inputs for a production engine to many hundreds of sensors for a development engine. Each sensor has a measurement uncertainty associated with it, and these uncertainties influence the weighting prescribed to each piece of data. As a result, the engine matching process is tedious and involves as much art as science. Herein lies the shortfall in capability.

The conundrum is summarized in Figure 1, where the measured data (the Y's) are described as a distribution and the model parameters (the X's) are represented as distributions that are continually refined as each new piece of data becomes available. A means for optimal robust estimation of engine parameters is required.

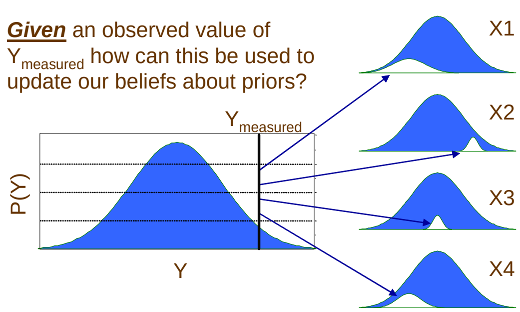

Figure 1: Probabilistic View of Optimal Engine Matching: Using Observed Data (Y's) to Deduce Most Likely Distributions on Engine Model Parameters (X's).

The ultimate goal is an automated method to calibrate steady-state turbine engine performance simulations such that they represent either a specific engine or a fleet of engines as selected prior to applying the calibration method. The method must be capable of achieving a progressively incremental calibration and avoiding re-processing of previously included information. The method must also take into account the level of uncertainty and the level of importance of the information used in the calibration.

This project is intended to lay the scientific and mathematical groundwork needed for a process which receives turbine engine test data from multiple arbitrary sources, receives characterizing information about the data (e.g., measurement uncertainty, level of relevance), processes the data and their characterizing information, and determines a calibrated state of the model. The attainment of this goal will require multidisciplinary integration of advanced optimization techniques, weighted least squares algorithms, Bayesian probability concepts, and statistical analysis.

References:

1. Roth and Mavris, "Estimation of Turbofan Engine Performance Model Accuracy and Confidence Bounds," ISABE 2003-1208, 16th International Symposium on Air-Breathing Engines, Cleveland, Ohio, USA August 31 - September 5, 2003.

2. Roth, et al, "High-Accuracy Matching of Engine Performance Models to Test Data," GT2003-38784, Proceedings of the International Gas Turbine Institute: 2003 ASME Turbo Expo, Atlanta, Georgia June 16-19, 2003.

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2. Investigation of Microchannel Cooling Critical Heat Flux

Flow-field probes have been used routinely to define thermodynamic properties, flow velocity/angularity, and chemical speciation of gas streams in turbine engines, rocket motors, and various ground test facilities [1-2]. A critical process necessary for the survival of these probes in extremely high-temperature environments, such as those found in vitiated facility flows and propulsion system exhausts, is the stable internal cooling of the probe structures. Without the internal cooling, probe temperatures well in excess of the melt temperature of non-refractory metals are possible, and most refractory metals would experience significant oxidation. Current interest in miniature embedded probe configurations [3] will limit the use of ceramics in probe construction because of their potential for thermostructural fracture and resulting foreign object damage. Therefore, micro-scale cooling configurations in metallic structures are anticipated for the miniature probe geometries.

The successful application of internal cooling, as demonstrated by the survival of current high-temperature flow-field probe designs, lies in the ability of the coolant to transition to multi-phase flow. However, this efficient method of cooling can be expected to break down at a limiting point known as the critical heat flux (CHF). For cooled metallic structures subjected to a high-temperature gas stream, this CHF condition is the point where the beneficial nucleate boiling in the coolant transitions to detrimental film boiling. An unstable temperature excursion in the structure follows the transition, typically well beyond the thermostructural limit, and in most cases even the melt temperature of the metallic structure. For this reason, the CHF in cooled metallic structures is referred to as the burnout condition, and is a critical design parameter in order to assess probe survivability and structural margins of safety.

Reasonable accuracy has been shown for analytical heat-transfer methods in the pure forced convection and nucleate boiling regimes. However, complexity of the boiling mechanisms at burnout, their unsteady nature, and the small scale of the heat-transfer processes have hindered the development of theoretical CHF models [4]. The analytical CHF correlations that have resulted are sensitive to the range of conditions for the data used, and reasonable confidence in any correlation for channel geometries and coolant conditions appropriate for flow-field probe designs has not been demonstrated, particularly for microchannel configurations.

The purpose of this research is to investigate CHF characteristics for cooling channel configurations and coolant conditions appropriate for miniature flow-field probes. Data from the investigation shall be used to demonstrate either high confidence in an existing CHF correlation, or generate a new correlation for future flow-field probe design predictions.

References:

1) Hiers, R.S. III and Hiers, R.S. Jr. “Development of Exit-Plane Probes for Turbine Engine Condition Monitoring,” AIAA 2002-4304, 38th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Indianapolis IN, 7-10 July 2002.

2) MacKinnon, H.M., Beitel, G.R., Hiers, R.S. III, and Catalano, D.R. “Advances in Aerodynamic Probes for High-Enthalpy Applications,” AIAA 2004-2594, 24th AIAA Aerodynamic Measurement Technology and Ground Testing Conference, Portland OR, 28 June – 1 July 2004.

3) Beitel, G.R., Jalbert, P.A., Plemmons, D.H., Hiers, R.S. III, and Catalano, D.R. “Development of Embedded Diagnostics for Internal Flow-Field Measurements in Gas Turbine Engines,” AIAA 2004-6865, AIAA/USAF Developmental Testing & Evaluation Summit, Woodland Hills, CA, 16-18 November 2004.

4) Beitel, G.R. “Boiling Heat-Transfer Processes and Their Application in the Cooling of High Heat Flux Devices,” AEDC-TR-93-3, June 1993.

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3. <u>Optical Tracking Without Targets Using Digital Cameras</u>

The rapidly advancing field of digital imaging holds tremendous potential for increasing the scope and utility of optical test techniques in aerodynamic test facilities, including PSP, TSP, LIF, DGV, PIV, pyrometry, skin friction measurement, and the measurement of position, attitude, motion, and deformation of test articles. Photogrammetry is a well-established technique to facilitate image registration for such applications, based on the use of predefined registration targets or (for similar views by multiple cameras) cross-correlation of natural image features. In addition, image registration techniques of this kind are desirable for the automated processing of flight data, such as store drops from a parent aircraft.

Existing techniques and existing commercial software packages become difficult to implement when no predefined targets are available, when model deformation occurs, when only a single camera is used, or when views from multiple cameras become too dissimilar (e.g., when a test article is viewed from orthogonal directions). Alternate means for performing image registration by a single or multiple cameras are sought, based, for example, on approximate knowledge of the shape of the test article. For example, a detailed geometry grid for the undistorted test article is typically available.

The new technique should afford ease of pre-test calibration and the ability to detect, track, and quantify changes in model shape during the course of a test. The new technique must be fast enough to be implemented in real time and require minimal manual interaction by the user. Research issues to be addressed include the definition, recognition, and extraction of suitable image features, strategies for dealing with multiple curved surfaces on a test article, performance under varying lighting conditions, the influence of shadows, how to deal with occlusions, and motion of the camera due to vibration or thermal effects.

1. Y. Ma, S. Soatto, J. Kosecka, and S. S. Sastry, An Invitation to 3-D Vision (Springer, New York, 2004).

2. F. Chen, G. M. Brown, and M. Song, "Overview of three-dimensional shape measurement using optical methods," Optical Engineering, Vol. 39, No. 1, pp. 10-22, 2000.

3. T. Liu, L. N. Cattafesta, III, R. H. Radeztsky, and A. W. Burner, "Photogrammetry applied to wind-tunnel testing," AIAA Journal, Vol. 38, No. 6, pp. 964-971, 2000.

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4. Network Loading Theory for Net-Centric Warfare Applications

T&E Need/Deficiency: In Network Centric Operations (NCO)/Network Centric Warfare (NCW), there are expected to be 1,000's of "nodes" on the network sharing information with other nodes. This is much like the internet. However, with the internet if the network fails to communicate a packet of information – the page simply needs to be reloaded, or part of the page doesn't work right. Generally, these internet networks are only tested to 20 to 50% of capacity and they are tested using simulations of about 500 nodes and then extrapolated. NCO/NCW will also have higher reliability standards and require using a greater percentage of capacity than standard networks.

What the AFFTC needs is to have a theoretical way to identify how many nodes are required on a NCO/NCW network in order to adequately test the network interfaces. NCO/NCW testing will require that we have a large number of nodes in the system. We need to have a theoretical basis for identifying the number of nodes and the types of nodes (live, virtual, constructive) required to create a realistic test environment.

Research Requirements: This research project should identify a theoretical basis for network loading that takes into account the information reliability requirements of NCO/NCW. The key is to understand at what point the network has been adequately stressed in testing to ensure that the information transfers will occur in a battlefield environment. A suggestion for the research is to combine network theory with distributed parameter control theory to determine a basis for ensuring observability and controllability of the network.

The first year should focus on network theory and the potential for joining network theory and distributed parameter control theory. The second year should identify theoretical conditions for ensuring controllability and observability. The third year should include simulated tests to demonstrate the adequacy of the theories developed.

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5. Radio Communication During Directed Energy Testing

T&E Need/Deficiency: Directed energy weapon testing will require instrumented targets with continuous radio link between the target and ground stations. This may be simple monitoring of the weapon and target via real time telemetry, which allows safety monitoring, collection of test point data, and forensic operations in case of catastrophe. With mobile targets, the radio link may also operate in the reverse direction to command various operations, including commanding flight termination.

During directed energy testing of lasers and radio frequency emitters, incident radiation can cause disruption of the radio signal, manifesting itself as problems ranging from momentary drop-outs of telemetry up to loss of vehicle control. We need techniques to overcome these disruptions to provide full testing capabilities and acceptable safety margins.

Research Requirements: The objective of this research is to understand physical phenomena and investigate different techniques to control adverse affects of incident high energy during testing.

Physical & Material Science – We need to understand underlying physical phenomena that affect communication path losses, such as ablation, local EMF fields and edge effects, particle and vapor emissions, chemical changes in target materials, and the local atmosphere. Short pulse, high power lasers, or HPMs may cause impulse temperature and shock effects. Researchers should search for and document any other possible phenomena that would affect telemetry or C^2 transmissions.

Engineering – We need to understand any communication implications of material damage such as antenna pattern and radiation efficiency changes or attenuation due to material property changes such as charring of composite materials.

Protocols & Procedures – We expect that myopic "hardening" of electronics and materials will not provide sufficient answers, given that the intent of the weapons developers is to overcome these efforts when employed by an enemy. Given that physical damage may occur and adversely affect the engineered communication systems, we want to investigate mitigating communication protocols, protections, or procedures. For instance, instead of a self-destruct signal, maybe we need a steady "don't destruct" signal monitor, or a FTS that can be initiated before an HPM impulse test and called back from execution after the test if appropriate hardware and software remains undamaged.

Dwell time of a laser weapon may allow freedom to sense the impinging radiation and take corrective actions. Maybe telemetry needs to be queued and burst back to ground stations or duplicate transmissions on alternate frequencies utilized?

The nature of the research may consist of mostly analysis and computation using mathematical models of the physics, radio emission/reception, and computed models of aircraft and aerodynamics. Experiments would be welcome. Proposed design of experiments for follow up of suggested approaches are necessary.

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6. Parameterized Reduced Order Modeling

T&E Need/Deficiency: Safely conducting flight testing and, particularly, envelope expansion flight testing are significant parts of the Flight Test Centers responsibilities. One key to conducting safe and efficient flight testing is getting the best predictive flight test simulation data possible; simulations that have been validated via flight test data. Many times the flight test conditions differ from the planned conditions. Ideally the flight test data would be compared to the simulation data for the conditions that were actually flown. However high fidelity simulations cannot run fast enough to support real time or near real time operations. Reduced order models can be built that can support near real time operations, but these models cannot easily be updated to reflect flight test data. At least in concept it should be possible to parameterize the reduced order model such that airspeed, altitude, mass distribution, structural stiffness, and any other appropriate parameter can be varied. This approach will not only reduce the number of reduced order models that need to be generated and imported into the control room, but also provides the means to update the model using data that is collected from flight test. This capability will increase both flight test efficiency and safety.

Research Requirements: This research should result in a systematic approach to building reduced order models that are parameterized by airspeed, altitude, mass distribution, and structural stiffness as a minimum. When built, the reduced order models should be within a user defined tolerance when compared to the high fidelity simulations that were used to create the reduced order model. After the reduced order models are produced that should be capable of rapidly producing simulation results for flight conditions as flown (not as planned); it should be easy to update the reduced order model using the mass distribution and structural stiffness parameters. If time permits the researcher may also investigate integrating the reduced order models into a manned flight simulator.

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7. Research in Evaluation Methods for Data Fusion-Capable Tactical Platforms and Distributed Multi-platform Systems in Electronic Warfare and Information-Warfare Related Missions

T&E Need / Deficiency: The capabilities of the evolving family of tactical aircraft platforms reflect the significant gains in information technologies in both the defense and public sectors. These platforms are clear examples of the Defense Department's commitment to the critical role of information in warfare and to the role of information operations as a companion to conventional mission operations. One key technology now embedded in platform avionics designs is that of Data Fusion. Data Fusion techniques will be employed on these platforms not only in single-ship operations but in multi-ship mission operations as well. In fact, multi-platform information interchange and distributed off-board Data Fusion processing is an inherent component of the Joint Strike Fighter (JSF) design and deployment concept. Data Fusion methods are also finding their way into various units that will support the operations of these new tactical platforms, to include airborne support platforms (e.g., AWACS, Joint Stars, UAVs), National Technical Means (NTM), as well as ground support centers (e.g., AOC, Distributed Common Ground Station (DCGS)) that enable information "reach-back" type capabilities. Further enhancing but also complicating the modern-day Intelligence, Surveillance, and Reconnaissance (ISR) environment are so-called "ubiquitous" sensor networks such as deployable, self-organizing arrays of unattended sensor systems (e.g., Unattended Ground Sensors (UGS)) whose data can be "exfiltrated" from their location and communicated to pertinent operational systems and platforms. To effectively design a distributed sensor manager which is based on the optimization of parameters, the data fusion metrics and design tradeoffs must be theoretically and empirically understood.

Research Requirements: Approaches to consider fall into two main categories: (1) research into the design and development of holistically-new Performance Evaluation (PE) architectures and processes, and (2) a series of case-study experiments that examine the effects of various important factors as a basis for preliminary assessments of such effects, and to exercise new PE designs, metrics, and methods.

The following table shows a characterization of two new potential PE process designs, and two proposed PE process modifications:

Factors Influencing Entirely New PE Process Design or Modification		
Process Challenge	**SUT Factor**	**PE Process Impact**
Major process conceptualization 1	Addition of SUT threat estimation capability	Design of PE process for evaluation of higher-level fusion processes; e.g., involves notions of estimated threat-to-truth association
Major process conceptualization 2	Platform-specific and interplatform sensor management logic	Design of "dual" of fusion-based PE process, to evaluate performance and effectiveness of SUT sensor resource management techniques
Major process modification 1	Algorithms for fusion-based target ID estimation	--Composite ID and kinematic-based track-to-truth scoring and assignment --Analysis and metrics for both integrated ID/kinematic performance evaluation and separable ID/kinematic evaluation
Major process modification 2	For any/all of above factors	Addition of automated PE process refinement logic

The two new PE process design approaches are the result of considering added System-Under-Test (SUT) (platform and/or multiplatform) capability to employ fusion-based techniques for hostile threat estimation and also to include dynamic sensor management both on single platforms (e.g. Electronically-Steered Antenna/Array (ESA) radars) and also via inter-platform, coordinated sensor resource-sharing. Current PE process baselines for fusion systems cannot handle these cases. One of the major modifications to consider would extend the state of the art PE baseline, which is focused on evaluation of target tracking (i.e. kinematically-focused) systems to deal with platforms that can employ fusion techniques for hostile target ID. The second major modification deals with enabling an automated capability to manage these complex PE processes in an automated way, at least to some degree; this is the equivalent of a Level 4 "process refinement" function in data fusion systems.

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8. Hypersonic Computational Fluid Dynamics to Support Aeroelastic Analysis

T&E Need/Deficiency: One of the greatest challenges to the testing and clearance of hypersonic aerial vehicles is at those speeds when anything unexpected occurs the time to react is so short that the vehicle must be destroyed. Consequently, the value of predictive analysis is even greater than for mere supersonic aircraft testing and clearance. All aircraft must be shown to be aeroelastically stable to clear the aircraft for operational use. The key to efficiently clearing an aircraft for operational use is the use of high fidelity coupled field simulations to predict the aeroelastic stability of the aircraft. This approach facilitates the flight test process because minimal time is lost due to predictive data and test data that do not correlate. In order to utilize this approach for flight testing hypersonic vehicles it is necessary to develop the predictive analysis capability. To accomplish this it is necessary to develop a Computational Fluid Dynamic (CFD) analysis capability that includes hypersonic fluid dynamic effects and that can be coupled with a Finite Element Method (FEM) code that analyzes the structure and the heat transfer within the structure.

An accurate hypersonic CFD analysis code could greatly increase the safety and efficiency of hypersonic flight testing. It will also be necessary to develop a FEM code that includes nonlinear thermodynamics and thermal elastic effects of the discontinuous materials and hot structures.

Research Requirements: A hypersonic CFD analysis code would need to include the effects of 1) the dissociation of gas molecules, 2) ionization of gaseous flow, and the resulting plasma field, 3) products of ablation being injected into the flow field, 4) effects of ablation on the aerodynamic shape, 5) and continuous gas dynamics vs. particle dynamics. There are codes available that address some of these requirements; however this research will need to incorporate all these effects into a single CFD code that is capable of operating as part of a coupled field aerothermalelastic code. Care must be taken in the development to maintain second order accuracy not only of the CFD code but also the overall coupled field analysis. In addition to the CFD analysis code there is also a requirement to develop a FEM code that can interact with the CFD code such that together they can perform aerothermalelastic analysis. The FEM code must include non-linear thermodynamic and elastic effects. Specifically, the heat transfer through discontinuous structures such as composite materials, joints, and plasma coated materials needs to be addressed. This research would develop the component computational methods needed to deal with these issues and the eventual integration of the resulting units into a coupled field analysis software code that would then be able to provide predictive aerothermoelastic analysis for hypersonic aircraft.

Note: Proposals responding to this topic should budget for $50k/year for the three-year project duration.

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9. Geometry Tolerant Pseudolite Navigation System

Problem/Need Description: The 746th Test Squadron at Holloman AFB has developed and presently utilizes the enhanced precision Central Inertial Guidance Test Facility (CIGTF) Reference System (CRS). CRS is a multi-sensor loosely / tightly coupled integrated navigation reference system used to evaluate position, velocity, and attitude performance of Global Positioning System (GPS), Inertial Navigation Systems (INS), and Embedded GPS/INS (EGI) Navigation Systems on a variety of vehicles and aircraft. The transponder / interrogator system permits position reference data to be obtained in a GPS jamming environment, because it operates outside the GPS frequency spectrum. The current transponder system does not provide centimeter level accurate position updates, which are required for high accuracy anti-jam GPS navigation system testing. The frequency spectrum that the transponders operate at has been allocated for use by the private sector. Due to the age of the transponder system it suffers from parts obsolescence thus making operation and maintenance a difficult and expensive task.

The 746 TS has been investigating the use of a GPS pseudolite system that provides ranging information from ground locations like the current transponder system. The new system is advantageous because it has increased accuracy over the transponder system, no frequency spectrum issues, and low cost operations and maintenance. There is one issue that affects this new system in the same manner as the transponder system. That issue is a poor geometry in an aircraft landing scenario. The poor geometry is the relative position of the aircraft receiver in relation to the ground transmitters. The result is a nearly co-planar arrangement in the pseudolite system which causes decreased accuracy and matrix singularities in measurement processing. In a jamming environment, the pseudolite system will dominate the accuracy of the flight reference system so it is very important that its accuracy is maintained for the entire flight region of any future aircraft testing. The landing scenarios will be very important for the testing of the Joint Precision Aircraft Landing System (JPALS).

The objective of this research would be to address the geometry challenge of an aircraft landing scenario for ground based pseudolite navigation systems.

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10. An Investigation into the Effects of Turbulent Length Scales on Flow Driven Diffusion Flames

Problem/Need Description: The turbulence level of the incoming flow and the resultant turbulent wakes generated off of the clutter elements found within an aircraft bay will define the fire propagation, as well as the fire suppressant delivery and mixing. The degree of turbulence and more importantly the length scales of the turbulent structures need to be documented for different geometry. For instance the larger length scale turbulent structures will readily transport gases, but are much less efficient in local mixing with surrounding air. Small-scale turbulent structures would provide an enhanced degree of mixing but would have a difficult time transporting large quantity gases to the region of interest.

A greater understanding of the effects of high turbulence levels (i.e., 5-20% turbulent intensity), generated by a turbulent flow passing over clutter elements, on fire propagation and suppression is needed. Most previous studies have fallen short in setting up a realistic boundary condition (highly turbulent flow) or only measured the overall turbulent intensity (TI). What is specifically needed is an understanding of how different turbulent length scales affect flame stabilization, fire suppressant transport, and fire suppressant mixing.

This study would support all full-scale T&E involving fires and airflow. Near term benefits include data for ongoing fire model development (VULCAN, WINFIRE). The potential mid-term benefit is improved simulator design for T&E efforts (both vulnerability and lethality) involving fire and airflow, e.g. aircraft engine nacelles, aircraft dry bays. In addition, an improved understanding of turbulent structure interactions would lead to improved fire suppression nozzle placement. Potential far-term benefits could be improved aircraft bay designs that prevent fires by preventing flames from stabilizing. Or a novel, lightweight fire suppression system could be designed based on the premise of altering the flow field in the vicinity of the fire thereby enhancing the effectiveness of a fire suppressant agent.

This effort should extend ongoing research on fire suppressant transport through a cylindrical array of clutter elements to include different turbulence levels, flow speeds and clutter geometry. The objective would be to begin to catalog the nature of the flow field in the presence of various clutter elements and access its impact on fire suppressant transport, agent mixing, and pool fire stability.

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11. Global Characterization of Dynamic Fuel Tank

Problem/Need Description: A capability to non-intrusively characterize the fuel/air interface and overall fuel tank environment undergoing slosh and vibration. Areas of interest include fuel surface, fluid motion, fuel vapor concentration changes, as well as fuel droplet size/distribution. This capability needs to be demonstrated in a test range setting.

The fuel tank of an aircraft is the largest presented vulnerable area of an aircraft yet even after the flurry of work conducted in the wake of TWA 800 it is still an area not well characterized. Accurate on-ground simulation, verified with limited in-flight data coupled with modeling would improve the capability to test aircraft fuel tank systems as part of Live Fire Testing and other lethality/vulnerability related test and evaluation exercises. While several advances in species measurement have brought the measurement of fuel tank constituents such as oxygen, fuel vapor, and nitrogen to the technology demonstration stage, globally characterizing the fuel/air interface with any accuracy has not yet been attempted.

The flammability envelope of a liquid fuel/air mixture under static conditions is well characterized although some variation occurs in wide-cut fuels, e.g. JP-8, due to differences in refinement, storage conditions, ageing, etc. But all references showing JP-8 flammability curves under dynamic fuel conditions are only represented by approximate boundaries due to the lack of data that quantitatively describes the events occurring within a fuel tank undergoing slosh and vibration. However, recent advances in the application of particle image velocimetry (PIV) now allows flow field and droplet information to be acquired in a dynamic fuel tank environment.

This effort should extend an ongoing examination of safe oxygen concentrations under a single fuel tank motion to include a range of representative motions, fuel temperatures, and fuel loading conditions. This information would then be used to develop correlations to help estimate fuel tank flammability under motions experienced by operational aircraft.

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12. Multi-element Antenna Phase Center Characterization

Problem/Need Description: The 746 Test Squadron (TS) at Holloman AFB, NM provides laboratory, field and flight test solutions for Navigation Guidance Systems that employ Global Positioning Systems (GPS). Typically, testing involves adaptive signal processing that exploit multi-element antennas arrays to mitigate GPS jamming. Multi-element antennas, or Controlled Reception Pattern Antennas (CRPAs), are used in both the development test item and the navigation reference system.

The position and velocity solutions from GPS antennas are calculated at the phase center of the antenna. The relative weighting of antenna elements changes when a CRPA is exposed to GPS jamming. This causes a physical movement of the phase center with respect to the rest of the antenna. The result is an error source that is not present in single element systems or in a CRPA that is not jammed. This new error source will degrade the accuracy of flight reference systems in addition to all developmental navigation systems that utilize multi-element antennas.

This effort should focus on antenna modeling. The first task would be to characterize the magnitude of phase center movement in a jamming environment. The second task would be to model and predict phase center movement in order to remove that source of error. The 746 TS has the test assets required to support the Research Specialist in the characterization testing.

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